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ORIGINAL PAPER

Plant diversity, population structure, and regeneration status in disturbed tropical forests in Assam, northeast India

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Abstract: We investigated the plant population structure and the phytosociological and regeneration status in two disturbed tropical forests in Assam Province, the Hojai Reserve Forest and Kumorakata Reserve Forest. A total of 166 species (80 trees, 20 shrubs and 66 herbs) of 136 genera and 63 families were recorded in both study sites. The disturbance index at the two sites, Kumorakata Reserve Forest and Hojai Reserve Forest, were recorded at 11.4% and 3.70% respectively. Reverse J-shaped population curve and exploitation of tree species in higher girth classes were recorded at both study sites. In the girth classes (10−30 cm, 30−60 cm, 60−90 cm and 90−120 cm in size) the percentage of cut stump density was higher than the percentage of individual living trees. The 18% (Kumorakata Reserve Forest) and 7% (Hojai Reserve Forest) species were recorded as "not regenerating." Illegal felling and over-exploitation of forest resources may lead to species-specific changes in the population structure and can alter the future structure and composition of the forests.

Keywords: plant diversity; regeneration; disturbance; population structure; Assam; India

Introduction

Knowledge about the plant diversity and regeneration status of particular forests is baseline information for the management and conservation of biodiversity. Natural regeneration is a central component of tropical forest ecosystem dynamics and is essential for preservation and maintenance of biodiversity (Rahman et al. 2011; Getachew et al. 2010). Along with regeneration, the most important characteristics of tropical and subtropical humid forests are their species richness, heterogeneity, and complex community organization (Mishra et al. 2005). Successful regeneration of a tree species can be predicted by the structure of their overall populations as well as sufficient numbers of seedlings, saplings, and adults (Pala et al. 2012; Saxena et al. 1984).

Both natural as well as manmade activities have an effect on species diversity, population structure, and natural regeneration of a forest ecosystem. Flood, fire, storms, the invasive species are some natural causes while illegal felling, over-exploitation of forest resources, encroachment, and domestic grazing are some man-induced causes that can affect the natural forest ecosystems. The conservation of biodiversity and human use of tropical forest resources in developing countries are in conflict with one another (Singh 1998) and degradation of tropical forests and destruction of habitat due to anthropogenic activities are the major causes of decline in global biodiversity (Mishra et al. 2004). In India, habitat destruction, over-exploitation, environmental pollution, and anthropogenic pressure are the major disturbances to forest ecosystems (UNEP 2001).

In view of the growing threat to biodiversity, it is important to see how natural communities and their structural attributes are affected by anthropogenic disturbances (Mishra et al. 2004). Phytosociological studies in different disturbed forests are well documented (Khan and Tripathi 1986; Ashton 1993; Burslem and Whitemore 1999; Bhuyan et al. 2003; Upadhaya et al. 2004; Khumbongmayum et al. 2006).

The present study was carried out to assess the plant population structure and phytosociological and regeneration status in two moist-deciduous tropical forests in Assam, the Hojai Reserve Forest and Kumorakata Reserve Forest.

Materials and methods

Study sites

The two study sites, Hojai Reserve Forest and Kumorakata Reserve Forest, are located toward the south of Nagaon district of

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Assam, in northeast India. The Hojai Reserve Forest is situated between the geographical limit of 92°49′30″–92°53′0″E longitude and 25°55′0″–25°58′0″N latitude at 76 m above msl, and the Kumorakata Reserve Forest is situated between 92°45′30″–92°47′30″E longitude and 25°57′0″–26° 0′30″N latitude at 65 m above msl. The rainy season starts in May and continues up to October, and the dry season begins in November and ends in April. The area of Hojai Reserve Forest is 948.2 ha and that of Kumorakata Reserve Forest having an area of 496.29 ha.

Methodology

We used the quadrat method for collection of phytosociological data during 2009-2010. Following a stratified random sampling approach, at each site, 50 quadrats of 10m × 10m size for the tree, sapling and seedling layer; 50 quadrats of 5m × 5m size for shrubs; and 100 quadrats of 1m × 1m size for herbs were randomly laid out. The size of the quadrat for sampling tree, shrub, and herb species was determined by the species-area-curve method (Muller-Dombois and Ellenberg 1974). Tree girth was measured at 1.3 m height from the base of an individual tree. Basal area, density, and importance value index (IVI) were calculated according to the formulae of Cottam and Curtis (1956). Individual trees having ≥30 cm girth were considered as adults, 30−10 cm were considered as saplings and ≤10 cm at the base were considered as seedlings. Each individual tree and its respective girth were recorded within the studied quadrat.

The regeneration status of tree species was determined based on the population size of seedlings, saplings, and adults (modified from Khan et al. 1987; Shankar 2001; Khumbongmayum et al. 2006). If the population size is seedling > sapling > adults, the regeneration status of tree species is “good regeneration”. If the population size is seedlings > or ≤ saplings ≤ adults, seedling ≤ sapling > adult, seedling ≥ sapling and the species had no adults, the regeneration status of tree species is “fair regeneration”. If the species survives is only in sapling stage, but no seedlings (saplings may be <, > or = adults), the regeneration status of tree species is “poor regeneration”. If a species is present only in adult form, it is considered as “not regenerating”. A species is considered as “new” or “new arrival” if the species are found only either in seedling or sapling stage without any adults.

The Shannon-Wiener diversity index (H') was calculated using the formula given by Shannon and Weaver (1969):

$$H' = -\sum_{i=1}^{s} p_i \ln p_i \qquad (1)$$

where, p_i represents the proportional abundance of the i^{th} species in the community.

Simpson’s index of dominance (C_D) was measured by formula given by Simpson (1949):

$$C_D = \sum_{i=1}^{s} (p_i)^2 \qquad (2)$$

where, p_i is the same as for the Shannon-Wiener diversity index. Similarity index (S) was calculated using the formula given by Sørenson (1948):

$$S = 2C/A+B \qquad (3)$$

where, A is the number of species in sample A, B is the number of species in sample B and C is the number of species common to both samples. Disturbance index (D_I) was calculated using formula given by Kanzaki and Yoda (1986):

$$D_I(\%) = B/T \qquad (4)$$

where, B is the basal area of cut trees and T is the total basal area of all trees including felled one.

Evenness index (e) was calculated using formula given by Pielou (1966):

$$e = H'/\log S \qquad (5)$$

where, H' is the number derived from the Shannon-diversity Index and S is the total number of species.

Results

Floristic composition

A total of 166 species (80 trees, 20 shrubs and 66 herbs) of 136 genera and 63 families were recorded at both study sites. In Kumorakata Reserve Forest, 96 species (44 trees, 14 shrubs and 38 herbs) of 83 genera and 39 families were listed. In Hojai Reserve Forest, 121 species (58 trees, 14 shrubs and 49 herbs) of 105 genera and 56 families were listed.

In Hojai Reserve Forest, 18 adult tree species of 15 genera and 15 families were recorded; whereas in Kumorakata Reserve Forest, 17 adult tree species of 14 genera and 12 families was recorded.. *Shorea robusta* (IVI 197) and *Ficus nervosa* (IVI 105) were the dominant adult tree species in Hojai Reserve Forest and Kumorakata Reserve Forest respectively (Appendix 1).

In the shrub layer, the *Chromolaena odorata* was the dominant species in both study sites. The dominant herb species in Hojai Reserve Forest were *Urena lobata*, *Panicum repens*, and *Borreria hispida* and *Ophiuros megaphyllus*, *Parthenium hysterophorus*,and *Mimosa pudica* in Kumorakata Reserve Forest (Appendix 1).

The basal area of adult trees (73.6 $m^2 \cdot ha^{-1}$); shrubs (3.7 $m^2 \cdot ha^{-1}$); and herbs (4.8 $m^2 \cdot ha^{-1}$) were higher in Kumorakata Reserve Forest than the Hojai Reserve Forest. A higher Shannon diversity index (2.15) for adult tree species was recorded in Kumorakata Reserve Forest. In both forests, herb diversity was found to be higher than adult trees and shrubs. The Simpson index (C_D) and evenness index was 0.44, 0.53 in Hojai Reserve Forest and 0.18, 0.76 in Kumorakata Reserve Forest for adult tree species. In

between Hojai Reserve Forest and Kumorakata Reserve Forest, shrubs showed high species similarity (57.14%), (Table 1).

Table 1 Ecological indices of adult tree, shrub and herb in Hojai Reserve Forest and Kumorakata Reserve Forest

Forests		Species richness	No. of genera	No. of families	Shannon index (H')	Simpson's index (C_D)	Evenness index (e)	Density (Stems ha^{-1})	Basal area (m^2ha^{-1})	Similarity index (%)
Hojai Reserve Forest	Trees	18	15	15	1.52	0.44	0.53	240	66.85	28.57
Kumorakata Reserve Forest	(≥30 cm DBH)	17	14	12	2.15	0.18	0.76	138	73.6	
Hojai Reserve Forest	Shrubs	14	13	7	2.05	0.19	0.78	5928	1.67	57.14
Kumorakata Reserve Forest		14	14	8	1.76	0.25	0.67	5072	3.07	
Hojai Reserve Forest	Herbs	49	47	30	3.24	0.06	0.83	217216	1.58	48.27
Kumorakata Reserve Forest		38	38	23	2.62	0.15	0.72	237100	4.8	

Population structure and regeneration status of tree species

A total of 53 out of 58 tree species in Hojai Reserve Forest and 35 out of 44 tree species in Kumorakata Reserve Forest (Fig. 1a, b) showed higher population size in lower girth classes. Overall, the population structure of all tree species showed reverse J-shaped GBH-density distribution curve but a reverse pattern followed by basal area showed J-shaped curve. Seedling and sapling population density was higher for the species *Shorea robusta* in Hojai Reserve Forest and for *Trewia nudiflora* in Kumorakata Reserve Forest (Appendix 2). The highest percentage of individual trees was recorded in the 0-10 cm girth class and the lowest in 60–90 cm girth class at both study sites (Table 2). In Kumorakata Reserve Forest, not a single individual was recorded in 90–120 cm girth class.

In Kumorakata Reserve Forest (46%) and Hojai Reserve Forest (43%), the highest tree species were included in the category of "new" regeneration status. In Kumorakata Reserve Forest (18%) and in Hojai Reserve Forest (7%) species were included in the "not regenerating" category (Fig. 2). The following species were in the "not regenerating" category: *Albizzia odoratissima*, *Artocarpus chaplasha*, *Bombax malabaricum*, *Schima wallichii, Albizzia procera*, *Bombax insigne*, *Careya arborea*, *Citrus decumana*, *Dillenia indica*, *Ficus bengalensis* and *Ficus nervosa*.

Disturbance Index

The disturbance index of Kumorakata Reserve Forest and Hojai Reserve Forest was 11.4% and 3.70% respectively. The highest cut stump density was recorded in Kumorakata Reserve Forest rather than in Hojai Reserve Forest (Fig. 3). In Kumorakata Reserve Forest, the highest density (388 ha^{-1}) of cut stumps was recorded in the girth class 10–30 cm, followed by 30–60 cm (284 ha^{-1}) girth class.

In Kumorakata Reserve Forest, cut stumps of *Trewia nudiflora, Bauhinia purpurea, Bombax insigne, Bombax malabaricum, Strablus asper, Garuga pinnata, Ziziphus jujuba, Citrus decumana, Albizzia lucida, Vangueria spinosa, Gmelina arborea, Crataeva nurvala* and *Zanthoxylum budrunga* were recorded. While in Hojai Reserve Forest, cut stumps of *Shorea robusta, Pterospermum acerifolium, Holarrhena antidysenterica, Lagerstroemia parviflora, Syzygium cumini, Cassia fistula, Careya arborea, Trewia nudiflora, Lagerstroemia flosreginae, Zizyphus rugosa, Terminalia belerica* and *Dillenia scabrella* were recorded.

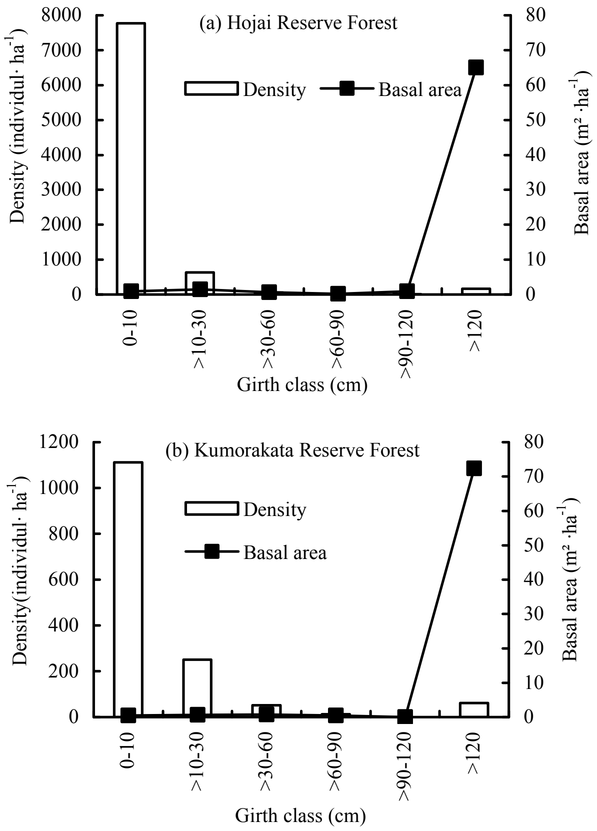

Fig. 1 Number of individuals and basal area of tree species recorded in (a) Hojai Reserve Forest and (b) Kumorakata Reserve Forest

Trewia nudiflora (642 ha^{-1}) had the maximum number of cut stumps in Kumorakata Reserve Forest. In Hojai Reserve Forest, *Syzygium cumini* (16 ha^{-1}) showed the highest cut stump density followed by *Shorea robusta* (12 ha^{-1}). In girth classes 10–30 cm, 30–60 cm, 60–90 cm, and 90–12 cm, the percentage of cut stump density was higher than the living tree individual density in both study sites (Table 2).

Table 2. Percentage distribution of living individual density and cut stump density in girth classes of Hojai Reserve Forest and Kumorakata Reserve Forest

Girth class	Living individual		Cut stump	
(cm)	HR	KR	HR	KR
0-10	89.92	75	0	2
10-30	7.39	17	42	53
30-60	0.63	3	23	39
60-90	0.05	1	6	4
90-120	0.09	0	19	1
>120	1.92	4	10	1

Notes: HR is Hojai Reserve Forest; KR is Kumorakata Reserve Forest.

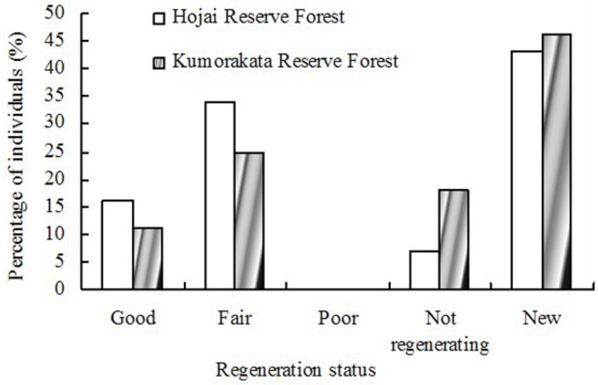

Fig. 2 Regeneration status of tree species in Hojai Reserve Forest and Kumorakata Reserve Forest

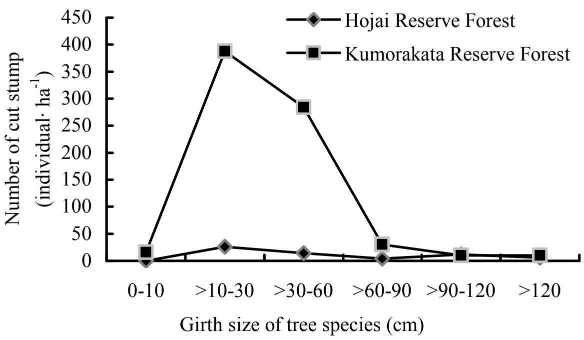

Fig. 3 Cut stump density (ha^{-1}) in Hojai Reserve Forest and Kumorakata Reserve Forest

Discussion

Floristic composition

The species composition of Hojai Reserve Forest (121) and Kumorakata Reserve Forest (96) was lower than 134 species recorded in the tropical moist sal (*Shorea robusta*) forest of west Bengal, India (Kushwaha and Nandy 2012) and the 123 species recorded in the tropical forest in Manipur (Devi and Yadava 2006). From the density and IVI value of the tree species, we can categorize the Hojai Reserve Forest as a sal (*Shorea robusta*) dominated forest. The basal area of adult trees, which was higher in Kumorakata Reserve Forest than Hojai Reserve Forest, was due to the presence of the high number of buttressed *Ficus nervosa* trees. In Bhuyan et al. (2003), the presence of buttressed tree species in a human-induced tropical forest stand also revealed greater basal area. .

Mishra et al. (2004) reported that the importance value of *Ficus nervosa* comparatively increased from undisturbed to highly disturbed in the sacred groves of Meghalaya, northeast India. Like Hojai Reserve Forest and Kumorakata Reserve Forest, Nath et al. (2005) also recorded *Chromolaena odorata*, *Urena lobata* as the dominant species in disturbed tropical wet evergreen forests of northeast India. From the similarity index value, we can estimate that the species were more common in the shrub layer than the herb and tree layer.

The Shannon diversity Index (H') for Indian forests ranged from 0.83 to 4.1 (Devi and Yadava 2006). The value of the Shannon diversity Index (H') in the present study therefore lies within the range reported for tropical forests. But the recorded density and Shannon diversity Index for adult tree species of the study sites were lower than the value recorded for density and diversity in the West Bengal moist sal forest of India (Kushwaha and Nandy 2012) and in the subtropical humid forest of Meghalaya, Northeast India (Upadhaya et al. 2004).

Many researchers supported the progressive reduction in tree density and Shannon diversity Index from undisturbed to highly disturbed (Rao et al. 1990; Bhuyan et al. 2003; Mishra et al. 2004). Basal area and stem density documented in response to disturbances can represent the structure of a forest stand and is also a useful indicator of human impact on a forest stand (Ingram et al. 2005).

Population structure and regeneration status of tree species

In our study sites, reverse J-shaped curves and exploitation of tree species in higher girth classes were recorded. The reverse J-shaped curve indicates heavy exploitation in higher girth classes in disturbed stands (Rao et al. 1990). These disturbances create small gaps in the forest canopy leading to higher light availability, which favours the seedling recruitment process of certain light-demanding species (Webb and Sah 2003). For example, the dominance of *Shorea robusta* seedlings in Hojai Reserve Forest may be attributed to the formation of certain favourable microsites. Dominance of this species in Hojai Reserve Forest also indicates that the sensitivity of species towards disturbance differs from species to species. The recorded 18% (Kumorakata Reserve Forest) and 7% (Hojai Reserve Forest) “not-regenerating” species shows vulnerability to existing disturbances, which may lead to local extinction of these species from the study sites in future. Hence, such human-induced activity may alter the future structure and composition of the forests.

Disturbance Index

In Hojai Reserve Forest, *Syzygium cumini* showed the highest cut-stump density followed by *Shorea robusta*. *Syzygium cumini* is preferred fodder and *Shorea robusta* is a well-known timber plant used by the local people, which may be the reasons for their exploitation. This finding was also documented at different forest sites (Pradhan et al. 2007; Sapkota et al. 2009). In Kumorakata Reserve Forest, cut stumps of *Gmelina arborea* and *Zanthoxylum budrunga* were recorded, but not a single living individual was recorded in any one of the girth class. Both study sites were under anthropogenic pressure due to collection of firewood and illegal felling of trees. These disturbances may lead to species-specific changes in the population structure.

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